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Knowledge, attitudes and practices relating to antibiotic use and antibiotic resistance among backyard pig farmers in rural Shandong province, China

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A R T I C L E I N F O

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A B S T R A C T

China is among the world's largest consumers of antibiotics for livestock, and the demand for meat protein continues to rise. Pig production takes place at a range of facilities, including backyard pig farms. The aim of this study was to describe the knowledge, attitudes and practices of backyard pig farmers concerning antibiotic use and resistance, and to observe household storage of antibiotics for use in pigs. We conducted a cross-sectional questionnaire survey among 271 rural residents with backyard pig farms in 12 villages in one town in Shandong province. The median number of pigs per backyard farm was 14, and 82 % (222/271) of participants reported not having had any training about raising pigs. Eighteen percent of participants (48/271) reported always or often adding antibiotics to feed to keep pigs healthy and prevent diseases, and a third (88/271) of participants believed that pigs should be given antibiotics when they stop eating. Thirty percent (82/271) reported having bought antibiotics in the previous year without having first spoken with a veterinarian. Antibiotics accounted for over half of all medicines stored (55 %, 197/358), and were observed in 31 % of all households (83/271). Less than half of participants (45 %, 37/83) from households in which antibiotics for pig use were found knew that they were storing antibiotics. The most common class of antibiotics stored for use in pigs was (Q)J01C beta-lactam antibiotics, penicillins (19 %, 37/197), followed by (Q)J01F macrolides, lincosamides and streptogramins (14 %, 28/197), and (Q)J01M quinolones (12 %, 25/197). These results provide important insights into how backyard pig farmers are using antibiotics in rural China and suggest potential targets for interventions to reduce unnecessary and inappropriate use.

1. Introduction

Antibiotic resistance has become a major threat to global health, food security and development worldwide, especially in low- and middle-income countries, such as China (Heddini et al., 2009; Xiao et al., 2011; Zhang et al., 2006). As in many countries, around half of all antibiotics used in China are consumed by livestock; these include uses as growth promoters, as well as to prevent and treat disease (Zhang et al., 2015). China was the largest producer and consumer of antibiotics for use in livestock in 2010, and the usage of antibiotics in livestock raising is predicted to increase by two-thirds by 2030 due to human population growth and the rising demand for meat protein (Van Boeckel et al., 2015). A recent OECD report suggested that China uses five times more antibiotics than the international average in pig and broiler production (mg/PCU), and that this excess is due to widespread use of antibiotics as growth promoters, violation of government policies on antimicrobial use, and misuse due to lack of knowledge and skills in using antimicrobials (Wu, 2019).

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1.1. Regulations and national activities on antibiotic use in agriculture in China

Initial regulations on antibiotic use in agriculture, such as the 2004 "Regulations on Administration of Veterinary Drugs" (Chinese State Council, 2004), focussed on the potential risks of drug residues in animal products and on counterfeit drugs (Wu, 2019). More recently, regulations have been developed to specifically address the challenges of antibiotic resistance. These include a "Catalogue of veterinary prescription drugs" which was published in 2014 (Chinese Ministry of Agriculture and Rural Affairs, 2014), in which 11 classes of antimicrobials that have high rates of resistance and are important in human healthcare were classified as prescription-only medicines; several antibiotic agents have also been banned for use in food animal production (Walsh and Wu, 2016; Wu, 2019). Further, there is an ongoing Five-Year National Action Plan of Comprehensive Management for Veterinary Medicines (2015–2019). The Ministry of Agriculture has included several targets to be reached by 2020, including halving the numbers of antimicrobial prescriptions in animal production, improving the monitoring system of antimicrobial use, and educating users and veterinarians on the rational use of antimicrobials (Wu, 2019).

1.2. Pig production and veterinary services in rural China

It is estimated that around half of all pigs on the planet are raised and eaten in China (Schneider and Sharma, 2014). Pig production occurs in a mixture of large-scale commercial farms, medium-scale specialised farms and small-scale backyard pig farms. These latter backyard farms are still highly prevalent in rural areas, and in 2014 farms with fewer than 50 pigs (often used as a definition for backyard pig farm (Qiao et al., 2016; Wu, 2019)) accounted for 95 % of pig farms and for 29 % of all slaughtered pigs in China. They are typically managed by a single household, similar to backyard farms in many other low- and middle-income countries (Graham et al., 2017). A veterinary and paraveterinary workforce supports backyard pig farmers in rural areas. This includes a mixture of private and government veterinarians and all veterinarians require a government licence before providing services. Although they can provide the same services, in practice private veterinarians are sought by farmers when their pigs are ill, and government veterinarians are more responsible for preventing and controlling diseases (e.g. through vaccinations). The para-veterinary workforce are permitted to diagnose diseases, but only qualified veterinarians are able to prescribe antibiotics, from a list of essential medicines which contains a wide range of broad- and narrow-spectrum antimicrobial agents (Chinese Ministry of Agriculture and Rural Affairs, 2014). Animal pharmacies must be licenced and should be inspected annually (DG Santé, 2019), and veterinary pharmacists must have either a practicing veterinary medicine certificate or a veterinary pharmacist qualification. Farmers pay for drugs and services of veterinarians and animal pharmacies, and they are obliged to keep records of medicines that they administer to their animals (DG Santé, 2019).

1.3. Knowledge, attitudes and practices of rural pig farmers

Although there have now been a few investigations of rural residents' knowledge, attitudes and practices (KAP) concerning antibiotic use for humans (Ding et al., 2015; Ye et al., 2017), similar studies among farmers with a focus on antibiotic use in agriculture are limited in China (Chen et al., 2016), as they are globally (Magouras et al., 2017). Such studies have the potential to identify modifiable risk factors associated with inappropriate antibiotic use and have been described as a crucial step for the design of strategies to combat the threat of antibiotic resistance (Magouras et al., 2017). Defining rational antibiotic use in agriculture is more challenging than in human medicine, due to the variety of ways in which they are used in and administered to livestock. Inappropriate uses may include: using antibiotics when they are not indicated; using the wrong antibiotic when an antibiotic is indicated; using the wrong dose, duration or form of an antibiotic; violating withdrawal rules or other regulations; using antibiotics as growth promoters or as long-term mass prophylaxis.

The present study was part of a larger One Health project called the Sino-Swedish Integrated Multisectoral Partnership for Antibiotic Resistance Containment (IMPACT) (Sun et al., 2018), conducted in a rural region in Shandong province where the population is relatively stable and small-scale household backyard pig farms are common. The aim of this study was to describe the current knowledge, attitudes and practices of backyard pig farmers in the study region concerning antibiotic use and resistance, and to observe household storage of antibiotics for use in pigs. The findings from this study will be used to inform the development of One Health educational interventions to improve antibiotic use in humans and animals (Sun et al., 2018).

2. Materials and methods

2.1. Study design, study setting and study population

A cross-sectional questionnaire study was conducted in households with and without backyard pig farms in rural Shandong province, China, in 2015. Shandong province, known as 'the stockbreeding province without a prairie', is located in eastern China and had a population of 97.9 million in 2014, living in 140 counties, half of which are rural. It is the second largest province in China by population and the third largest by gross domestic product. Its rural areas are generally similar to other rural areas in eastern China in terms of education and health indicators.

The full study protocol for the IMPACT research programme has previously been published (Sun et al., 2018). The study area of a single town in one county was pragmatically selected based on the presence of local infrastructural support necessary to coordinate all components of this large research programme (including a baseline assessment; a pilot package of interventions over a one year period; and a repeated data collection), and on the town being broadly representative of rural Shandong province including in terms of prevalence of backyard pig farms. The study population was selected using a multistage cluster sampling method using background data collected by the local Center for Disease Control and Prevention (CDC) prior to the main data collection. First, twelve of seventeen villages around the town were selected so as to maximise i) the number of included backyard pig farms, and ii) villages that had human healthcare clinics. The villages each had between 100–350 households, of which 10–20% had backyard pig farms (similar to the national average (Qiao et al., 2016)). Second, in each of these villages up to 35 households with backyard pig farms according to the background CDC data were randomly selected, i.e. if a village had fewer than 35 household backyard pig farms, all were selected. The target of 35 households with backyard pig farms in each village was chosen based on a power calculation for all components of the research programme (Sun et al., 2018) that would lead to a total of 65 households in each village, and an approximately equal number of households with and without backyard pig farms, accepting that some backyard pig farms may not have pigs throughout the entire study period. We defined backyard pig farms as farms that contained at least one but not more than 49 pigs (Qiao et al., 2016), to avoid including larger scale commercial farms with major differences in pig production practices. Local study coordinators visited each selected household and asked for the individual who worked most closely with the pigs in their backyard farm to be available on the day of data collection.

2.2. Survey tool

The questionnaire was developed by experts from Sweden and China in veterinary medicine, clinical medicine, public health and healthcare systems. The questionnaire (included as Supplementary material) included 95 items divided into sections, including socio-demographics; health status; KAP towards antibiotic use for humans; backyard pig farm characteristics; KAP towards antibiotic use for pigs; backyard pig farm biosecurity practices; storage of medicines for use in humans, and in pigs. The questionnaire was drafted in English, translated into Mandarin Chinese, piloted in ten households in June 2015, modified, back-translated into English, and finally verified.

2.3. Data collection

The selected households were visited between 19th-26th July 2015 and the individual who worked most closely with the pigs in their backyard farm was invited to respond to the questionnaire; if they were not available then any adult resident aged 18 years or older in the household was invited to participate. Residents were interviewed by public health master's students from a local university, and they had received training in interviewing. In addition, participants were asked to show which medicines they were storing in their homes for human use or for pig use. Interviews were carried out in Mandarin Chinese and responses were recorded in simplified Chinese.

2.4. Data management and analyses

All questionnaires were collected and cross-checked. Data was double-entered in Microsoft Access 2007 (Microsoft Corporation, Redmond, WA, USA) in simplified Chinese, translated into English, and then exported into SPSS. All statistical analyses were carried out using SPSS version 19.0 (IBM Corporation, Armonk, NY, USA). Descriptive analyses included frequencies and percentages for categorical variables, and means and standard deviations (SD) for continuous variables. Medicines that had been stored were classified into five categories: antibiotics, anti-inflammatories, traditional Chinese medicines, anti-parasitics and other medicines (i.e. medicines that could not be identified or that did not belong to any of the other categories). All antibiotics were coded according to the Anatomical Therapeutic Chemical (ATC) classification system (WHO Collaborating Centre for Drug Statistics Methodology, 2017a) and ATCvet (WHO Collaborating Centre for Drug Statistics Methodology, 2017b) and categorized by classes and substances.

Adjusted odds ratios were calculated to identify factors associated with household storage of at least one antibiotic for use in pigs. Independent variables included demographic and farm characteristics, and KAP towards antibiotic use in pigs. Responses to some KAP questions were dichotomised into binary variables ('Agree' versus ['Disagree' or 'I do not know']). Adjustments were made for sex, age and education level of respondent, but we did not attempt to adjust for clustering at the village level. All statistical tests were two-tailed and were considered statistically significant if $p < 0.05$.

2.5. Ethical approval

Participation in the study was voluntary. Informed consent was obtained from all participants immediately prior to their responding to the survey, either verbally or in writing. Participants were told that the survey was part of a research project on antibiotic resistance in humans and animals. Ethical approval was obtained from the first Affiliated Hospital, College of Medicine, Zhejiang University, China (reference number 2015#185 and 2015#283).

3. Results

3.1. Participants

A total of 271 households with backyard pig farms at the time of data collection participated in the face-to-face questionnaire. A median of 25 households with backyard pig farms were included in each village (range 7–38). All but 12 of the respondents (4.4 %) reported having daily contact with animals on most days; of these 12 respondents, 11 still reported their occupation as "farmer". The median number of pigs per backyard farm was 14, including 29 households with more than 49 pigs at the time of the study. These larger pig farms were included in the analyses as they were still considered to be small-scale farms, with a median of 7 sows (interquartile range: 5–10) and 80 piglets (interquartile range: 60–118) at the time of study. The median number of sows at farms with 49 or fewer pigs was 2 (interquartile range: 1–3). Supplementary Fig. 1 shows the distribution of total pig and sow numbers per farm.

Table 1
Characteristics of participants and their farms (Shandong Province, 2015, n = 271).

Variables	Frequency (%), or mean ± SD
Demographic characteristics	
Sex	
Male	170 (63)
Female	101 (38)
Age (years)	53.4 ± 7.8
Educational level	
Primary school or below	138 (51)
Middle school	101 (38)
High school or above	32 (12)
Primary occupation	
Small-scale animal farmer	226 (83)
Other type of farmer	28 (10)
Other*	17 (6)
Number of residents in household	2.8 ± 0.1
Farm characteristics	
Number of pigs	
≤14 pigs	140 (52)
> 14 pigs	131 (48)
Type of pigs raised	
1) Sows, with piglets raised to slaughter	164 (61)
2) Sows, with piglets that are sold after weaning	40 (15)
3) A mixture of 1) and 2)	42 (15)
4) Piglets that are bought and raised to slaughter	16 (6)
5) Other	9 (3)
Type of feed used for pigs	
Commercial feed	200 (74)
Own feed	125 (46)
Feed from another farmer	10 (4)
Other	2 (1)

* Examples of other professions included: worker on a commercial farm; village administrator; businessman.

Table 1 summarises the respondents' demographic characteristics and the characteristics of their backyard pig farms. Participants had been raising pigs for a mean duration of 11.1 years (SD 8.3 years) and 18 % (49/271) of the participants reported that they had had training about raising pigs. This training included attending professional courses (7 %, 20/271), training from relatives, neighbours or friends (8 %, 21/271), or a mixture of the two (3 %, 8/271). Male and female participants were equally likely to report having had some form of training (19 % [32/170] for males vs. 17 % [17/101] for females). Participants from farms with more than 49 pigs at the time of study were not more likely to have had training than participants from farms with 49 or fewer pigs (81 % vs. 79 %), neither were participants who reported their primary occupation as small-scale animal farmer (17 % [40/226] vs. 20 % [9/45] for "other occupation"). Fifty percent (135/271) of participants used only commercial feed for their pigs, and 22 % (66/271) used only their own feed.

3.2. Knowledge, attitudes and practices towards antibiotic use in pigs and antibiotic resistance

A third of participants (35 %, 97/271) reported knowing what antibiotics are. Male respondents were more likely to report knowing what antibiotics are (45 % vs. 21 % for females, $p < 0.001$), and to correctly identify two antibiotics from a list they were shown of 15 common medicines that contained four antibiotics (39 % vs. 17 %, $p < 0.001$).

Participants were asked to suggest two pig diseases that are normally treated with antibiotics. Thirty percent of participants (80/271) gave answers, and most of these (75 %, 60/80) included diarrhoea. The second most common answer was respiratory tract infection diseases (29 %, 23/80) such as cough and running nose. Other answers included foot and mouth disease (FMD) (19 %, 15/80), inflammation (4 %, 3/80), stopping eating (3 %, 2/80), bacterial infections (3 %, 2/80), parasites (1 %, 1/80) and pneumonia (1 %, 1/80). Male and female respondents were similarly likely to give answers (31 % for males vs. 27 % for females), as were respondents who stated their primary occupation was small-scale animal farmer (31 % vs. 22 % for "other occupation", $p = 0.24$). After these questions, all participants were told that antibiotics are medications that are used to treat bacteria that cause certain infections, in order to be able to answer the remaining questions on the questionnaire.

Fig. 1 shows participants' attitudes towards using antibiotics and medications in pigs on their farms. There was a borderline significant trend towards male participants being more likely than female participants to state that they know when their pigs need medications (81 % for males vs. 71 % for females, $p = 0.06$), but otherwise male and female participants reported similar attitudes, as did participants who did and did not consider their primary occupation to be small-scale animal farmer. Participants who thought that it was expensive to buy antibiotics for pigs were more likely to believe that it was good to keep leftover antibiotics at the farm (69 % [59/86] vs. 45 % [84/185], $p < 0.001$).

Participants' self-reported practices towards antibiotic use for their pigs are shown in Table 2. There was a trend towards male farmers being less likely to seek advice from veterinarians (56 % for males vs. 66 % for females, $p = 0.11$), and male and female farmers were equally likely to seek help from other farmers (25 % for males and 28 % for females). Males were more likely to purchase antibiotics from animal pharmacies than from veterinarians (51 % vs. 31 %, $p < 0.001$), whereas female farmers did not show a preference (41 % [animal pharmacy] vs. 38 % [veterinarians]). Male farmers were more likely to report having purchased antibiotics in the previous year without speaking with a veterinarian (37 % vs. 19 % for females, $p = 0.002$); this result remained significant when restricted to the subgroup of respondents who had earlier reported knowing what an antibiotic is (46 % [35/76] for males vs. 19 % [4/21] for females, $p = 0.02$). Participants who thought it was expensive to consult with veterinarians were not more likely to report having purchased antibiotics in the previous year without speaking with a veterinarian.

Table 2
Participants' self-reported practices towards antibiotic use (Shandong Province, 2015, n = 271).

Self-reported practices	Frequency (%)
Demographic characteristics	
When my pigs are sick, I seek advice from*	
A veterinarian	163 (60)
An animal pharmacy	56 (21)
Other farmers	70 (26)
Nobody	45 (16)
I use antibiotics	
Always or often in feed to keep pigs healthy and prevent diseases	48 (18)
For all pigs in a pen when some are sick	75 (28)
Only in pigs that are showing disease	137 (50)
No response provided	11 (4)
I usually buy antibiotics for my pigs from*	
A veterinarian	117 (43)
An animal pharmacy	157 (58)
A human pharmacy	4 (2)
Other	20 (7)
In the past year, I have purchased antibiotics for my pigs without first speaking with a veterinarian	
Yes	82 (30)
No	189 (70)

* For these questions, participants could select multiple responses.

Just over a quarter of participants (27 %, 72/271) reported that they worried about antibiotic resistance. Participants were equally likely to believe that bacteria (28 %), humans (35 %) and animals (32 %) can become resistant to antibiotics. Furthermore, 23 % (63/271) of the participants believed that bacteria, humans and animals can all become resistant to antibiotics.

3.3. Storage of medicines and antibiotics for use in pigs

Thirty-nine percent of households (107/271) were observed to be storing at least one medicine for pig use at the time of the study, with storage more commonly observed when the participant was male (48 % vs. 25 % for females, $p < 0.001$). In total, 358 medicines were observed in the households and reported to be for use with pigs. Antibiotics accounted for over half of all medicines (55 %, 197/358),

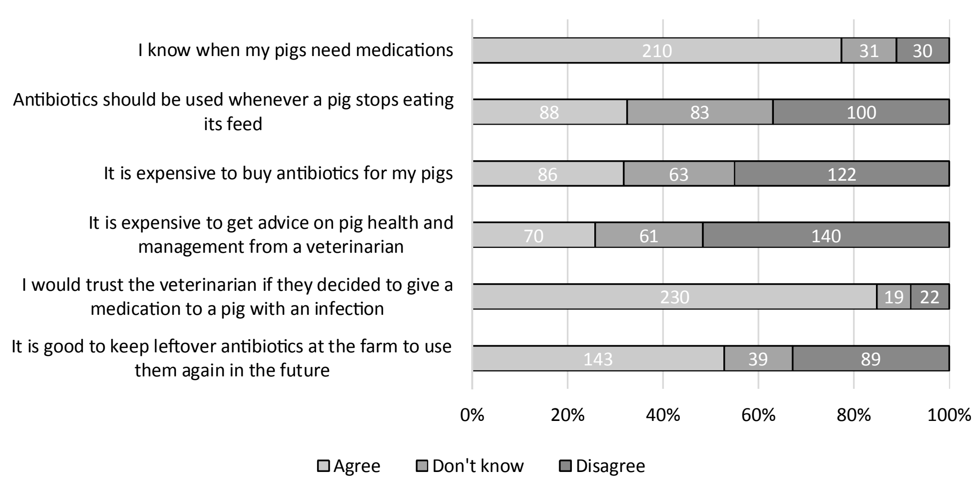

Fig. 1. Participants' attitudes towards antibiotic and medication use for pigs (n = 271).

Table 3
Factors associated with observed storage of antibiotics for pig use (Shandong Province, 2015, n = 271).

Factors	Adjusted OR (95 % CI)[#]	P-value
Demographic characteristics		
Age (years)*	0.99 (0.96, 1.03)	0.64
Male sex	**2.18 (1.18, 4.02)**	**0.01**
Education level: middle school or higher	1.04 (0.69, 1.57)	0.84
Number of family numbers*	1.11 (0.88, 1.41)	0.37
Occupation: small-scale animal farmer	1.28 (0.53, 3.45)	0.60
Farm characteristics		
Duration of raising pigs (years)*	0.98 (0.95, 1.02)	0.38
Number of pigs > 14	1.61 (0.94, 2.74)	0.08
Has had training on raising pigs	**2.80 (1.45, 5.39)**	**0.002**
Knowledge		
Reports knowing what antibiotics are	1.04 (0.58, 1.84)	0.91
Thinks that bacteria can become resistant to antibiotics	0.95 (0.51, 1.77)	0.87
Thinks that humans can become resistant to antibiotics	1.04 (0.58, 1.87)	0.89
Thinks that animals can become resistant to antibiotics	1.02 (0.56, 1.85)	0.96
Attitudes		
Worries about antibiotic resistance	0.92 (0.49, 1.70)	0.78
Knows when their pigs need medications	**2.19 (1.06, 4.50)**	**0.03**
Thinks it is good to keep leftover antibiotics for future use	**2.87 (1.64, 5.02)**	**< 0.001**
Trusts the veterinarian if they give medicines to a pig with an infection	1.85 (0.80, 4.27)	0.15
Thinks it is expensive to get advice on pig health and management from a veterinarian	1.26 (0.70, 2.29)	0.44
Thinks it is expensive to buy antibiotics for my pigs	1.69 (0.97, 2.95)	0.06
Thinks that antibiotics should be used whenever pigs stop eating feed	1.61 (0.92, 2.79)	0.09
Practices		
When pigs are sick, seeks advice from:		
Professionals: veterinarians or animal pharmacies	1 (reference)	0.38
Non-professionals: other farmers/nobody	1.27 (0.75, 2.14)	
Uses antibiotics:		0.05
Only in pigs showing diseases	1 (reference)	
For all pigs in a pen, when some of the pigs in the pen are sick	1.20 (0.65, 2.25)	
Always or often in feed, to keep the pigs healthy and prevent disease	1.98 (0.99, 3.95)	
Usually purchases antibiotics from:		
Veterinarians[+]	1.41 (0.83, 2.41)	0.21
Pharmacies[+]	0.92 (0.53, 1.58)	0.76
Has purchased antibiotics in the past year without first speaking with a veterinarian	**2.33 (1.33, 4.08)**	**0.003**

Results in bold were considered to be statistically significant ($p < 0.05$).
[#] Adjusted for age, sex, and education level.
* Age of respondent, number of family members in household, and duration of raising pigs were analysed as linear variables.
[+] Reference group for each variable is all other possible responses (i.e. for the variable "veterinarians", this includes pharmacies; market; another household; other).

and were observed in 31 % of all households (83/271). Other medicines stored in households included traditional Chinese medicines (23 % of all medicines observed, 81/358), anti-parasitic drugs (8 %, 29/358), anti-inflammatory drugs (3 %, 12/358), and other medicines (11 %, 39/358).

Of the households that stored antibiotics, 33 % (27/83) stored one antibiotic, 39 % (32/83) stored two antibiotics, and 28 % (24/83) stored three or more antibiotics. The most common class of antibiotics stored for use in pigs was beta-lactam antibiotics, penicillins ((Q)J01C; 19 %, 37/197), followed by macrolides, lincosamides and streptogramins ((Q)J01 F; 14 %, 28/197), and quinolones ((Q)J01 M; 12 %, 25/197) (eTable 1 in the Supplement). The most common antibiotic substances found in the households were amoxicillin ((Q)J01CA04; 10 %, 20/197), lincomycin ((Q)J01FF02; 10 %, 20/197) and oxytetracycline ((Q)J01AA06; 8 %, 15/197) (eTable 2 in the Supplement).

Five factors were associated with storage of antibiotics for pig use (Table 3): male sex; having had training on raising pigs; reporting knowing when pigs need medications; thinking that it is good to keep leftover antibiotics; and having purchased antibiotics in the previous year without speaking with a veterinarian.

Less than a half of participants (45 %, 37/83) from households in which antibiotics for pig use were found knew that they were storing antibiotics. Participants were more likely to identify which medicines they had stored were antibiotics if they had earlier reported that they knew what antibiotics are (50 % [18/36] vs. 21 % [10/37], $p < 0.01$), but there was no significant association with the respondent's sex, primary occupation, education level or having attended training on raising pigs.

4. Discussion

We used a cross-sectional questionnaire to assess the knowledge, attitudes and practices of a large number of backyard pig farmers in one town in rural Shandong province on antibiotic use, and we directly observed which medicines for pig use were stored in their households. We believe that many of our findings will be generalizable to backyard pig farmers in other rural areas in China since small-scale backyard pig farms are quite homogenous, as are the available veterinary healthcare services, and all are subject to the same national government regulations.

4.1. KAP towards antibiotics and antibiotic resistance among pig farmers

We found that participants had low levels of knowledge on what antibiotics are, on how and why antibiotics should be used, and on antibiotic resistance. These knowledge levels are similar, however, to other studies conducted among animal farmers in low-and middle-income countries including Sudan (Eltayb et al., 2012), Ghana (Osei Sekyere, 2014), Cambodia (Om and Mclaws, 2016) as well as in high-income countries including Spain (Moreno, 2014), Canada (Marvin et al., 2010) and Denmark (Vaarst et al., 2003). These low knowledge levels are not an unexpected finding, given that very few farmers in our study had had any form of training on raising pigs, with only 10 % having attended a professional course. It is likely that farmers instead gain knowledge from their practical work experience and conversations with other farmers. Educating both farmers and veterinarians is one of the key goals of the Chinese National Action Plan on Antimicrobial Resistance (Xiao and Li, 2017).

Only a minority of participants knew which pig diseases normally need to be treated with antibiotics. Diarrhoea was the disease most frequently mentioned by participants that should be treated with antibiotics, and several of the most common diarrhoeal disease in pigs are of bacterial origin (e.g. neonatal diarrhoea, weaning diarrhoea, swine dysentery and porcine proliferative enteritis). Nonetheless, an appropriate aetiological diagnosis and preferably susceptibility testing are important for deciding whether an antibiotic is needed for treatment of diarrhoea, and if so, which antibiotic should be selected. More generally, a diagnosis should be made by a qualified veterinarian before any medicines are administered, as advocated in international standards (OIE, 2014). We found that 40 % of our participants reported that they do not usually seek advice from veterinarians when their pigs are sick, even though most participants had not had training on raising pigs. Furthermore, a third of participants reported that they had purchased antibiotics in the past year without first consulting with a veterinarian (in practice, a farmer does not need to have a prescription to obtain antibiotics from an animal pharmacy). We did not attempt to comprehensively assess potential barriers to seeking advice from veterinary professionals, but there were very high trust levels in veterinarians and a half of our participants did not consider consulting them to be expensive. Graham et al. have previously suggested that it is likely that backyard farmers in such settings lack access to necessary veterinary technical assistance (Graham et al., 2017). Local data suggests that there should be one private veterinarian and two para-veterinary professionals per six to twelve villages in the study region, but we do not have any specific supporting information on the training of these individuals, nor on the levels of demand for their services. Worryingly, a recent OECD report mentions that the number of veterinarians working in rural China has rapidly fallen in recent years because many have chosen to move to urban areas to meet growing demand from pet animal owners (Wu, 2019).

Foot and mouth disease (FMD) was the third most frequent response by participants of a disease that should be treated with antibiotics; this is a surprising finding given that FMD is a highly epidemic viral disease, subject to strict national and international regulations, typically through culling of affected animals and vaccination of animals at nearby farms. We are unable to explain this finding, but one hypothesis is that farmers may know that an injection is needed to prevent FMD, but they do not know that this is a vaccine and not an antibiotic.

A fifth of respondents reported that they always or often used antibiotics in feed to keep pigs healthy and prevent diseases. This is likely to be an under-estimate of the use of antibiotics as growth promoters because farmers may not always be aware of the contents of commercial feed (used by three-quarters of respondents), and because we did not review the contents of the commercial feeds in use at the time of the study. Antibiotics have historically been allowed to be used as feed additives for both promoting growth and preventing disease in China, although in late 2016 the formal Ministry of Agriculture Announcement prohibited using colistin as a feed additive in order to extend its clinical longevity (Walsh and Wu, 2016). More recently, Ministry of Agriculture Announcement 2638 has specified that only 11 antimicrobial agents and compounds can be used as antibiotic growth promoters in feed (Wu, 2019).

4.2. Storage of antibiotics for pig use

A third of households were observed to be storing antibiotics for use in pigs, and antibiotics constituted around half of all medicines stored. Many of the antibiotics stored in households are considered by the World Health Organisation to be critically important antibiotics for human medicine, including macrolides and quinolones (the second and third most common classes stored) (World Health Organization, 2017). To our knowledge, no previous study has evaluated the prevalence of antibiotic storage in small-scale pig farms in China, or what factors are associated with antibiotic storage, and so we are unable to directly compare our results to other similar studies. However, the specific antibiotic agents stored in households in our study are very similar to the types of antibiotics reported to be used during pig production in 60 pig farms in a province in Southern China (He et al., 2011; Wu, 2019). In order to simplify data collection we did not attempt to capture information on the forms or volumes of antibiotics stored, nor on their storage locations. This means that we cannot speculate on the intended uses of the stored antibiotics (for example, mass prophylaxis, compared with treatment of individual pigs), nor on the potential negative impacts of storage location on antibiotic efficacy. It would be valuable for future studies to collect this information.

Previous studies in human medicine have shown that storage of antibiotics is a significant risk factor for self-medication, in part due to easy access (Lv et al., 2014; Ocan et al., 2015). We do not believe that storage of antibiotics for pig use is itself as strong a marker for irrational antibiotic use in pigs as it is human medicine. Indeed, storing antibiotics for future use under the guidance of a veterinarian may be an appropriate and financially beneficial behaviour. Nonetheless, we found that storage of antibiotics was associated in univariate regression analysis with purchasing antibiotics without first speaking with a veterinarian, as well as two other attitudes and behaviours that almost reached statistical significance and that could contribute to irrational antibiotic use: thinking that antibiotics should be used whenever pigs stop eating their feed, and always or often using antibiotics in feed to keep pigs healthy and prevent disease. Interestingly, participants who reporting having had training on raising pigs were more likely to be storing antibiotics, which implies that the content of such training needs further exploration. Perhaps most importantly, over half of participants from households in which stored antibiotics were observed were not aware that they were storing antibiotics, and this lack of awareness may be a risk factor for irrational antibiotic use. We suspect the main explanation for this finding is that respondents in general had little knowledge of what antibiotics are, and so could not identify the stored medicines as antibiotics. It is, however, possible that some respondents wished to conceal that they knew that the medicines were antibiotics.

4.3. The roles of respondents on their farms

An important methodological limitation is that we have not been able to take into account the specific roles of our respondents in their backyard farms, other than inviting the individual who works most closely with the pigs to respond to the questionnaire. Almost all respondents reported that they had daily contact with animals, and over 80 % stated their primary occupation as small-scale animal farmer; we did not expect this latter figure to be 100 % since some households will have been keeping pigs primarily for their own consumption rather than as the major source of household income. We found only minor differences in the responses between those who considered their primary occupation to be small-scale animal farmer, and those who stated other occupations. Together, these results and the patterns of responses to other questions strongly suggest that our survey respondents were significantly involved in managing their backyard farms.

It is plausible that household members take on different responsibilities in their backyard farms, potentially based on gender; this is relevant to our analyses since over 95 % of households had two or more residents. Overall, however, men and women were equally likely to have attended different types of training on raising pigs, and they shared similar attitudes and practices towards antibiotic use in pigs, as well as similar health-seeking behaviours for their pigs. We did find that men were more likely to report having bought antibiotics in the previous year from a veterinarian, which suggests that men may have greater responsibility for decision-making on financial matters concerning the backyard farm (e.g. purchasing medicines). However, an alternative explanation for this result is that men are more likely than women to use antibiotics for their pigs; this could help explain why households with male respondents were more likely to be found to be storing antibiotics. A small study in small- and medium-scale farms in Jiangsu province in Eastern China found a higher risk of inappropriate drug use for pigs among famers that were male (Chen et al., 2016). Interestingly, some of our results suggest that male farmers behave more independently of veterinary healthcare professionals than female farmers do, and this could lead to increased antibiotic use; for example, male farmers were much more likely to acquire antibiotics from animal pharmacies than from veterinarians (compared with female farmers), and there was a trend towards male farmers being less likely than female farmers to seek advice from veterinarians when their pigs are ill. In our earlier study in the same households we observed no differences between male and female respondents in storage rates of antibiotics for human use (Dyar et al., 2018), so we think it is unlikely that female respondents purposefully concealed storage of medicines.

4.4. Additional methodological considerations

Questionnaire surveys can suffer from reporting and recall bias, as well as bias due to social expectations. Efforts were made to reduce these biases by ensuring participants were aware that the study was confidential, and that there would be no judgment or consequences. We included twenty-nine households with fifty or more pigs in our analysis, which was distinct from our original definition of a backyard pig farm. We did not exclude these from the analyses because most of these larger farms still had under 100 pigs, and so were still considerably smaller than large-scale commercial farms (considered to be > 500 pigs) (Wu, 2019). Furthermore, we found minimal differences between farms with fifty or more pigs and those with fewer than fifty pigs in terms of participants' characteristics and their KAP towards antibiotics (data not shown).

A strength of the study is that we assessed storage of medicines through direct observation, rather than relying on participant recall; this also allowed us to ask whether participants were aware if the individual medicines stored were antibiotics. Although participants were aware the survey concerned antibiotics, we do not think this will have disproportionately influenced the reported storage rate of antibiotics, given the low frequency of respondents who reported knowing what antibiotics are. Respondents were asked to only show medicines that were stored for use in pigs, but it is possible that medicines for use in other animals were shown and/or recorded by the data collectors; respondents were asked separately to show which stored medicines were intended for human use. It would be valuable for future studies to check the labels on stored medicines to further verify they are intended for animal use, as well as collecting information on their forms and storage location. There is an important need to better understand the patterns of antibiotic consumption in livestock across all production scales (Magouras et al., 2017). Simple "point prevalence" style studies of storage such as ours can start to provide insight into the types of antibiotics that are being used on backyard farms within a region, and so we suggest that this approach should be considered in other settings where larger scale systems to monitor antibiotic consumption are likely to prove difficult to resource and implement. A limitation of such studies, though, is that rates of storage of medicines may vary throughout the year.

Our results should be highly representative of the immediate study region since we included all backyard pig farms present in ten out of the twelve selected villages. Overall, we also believe that many of the main findings of this study (such as low knowledge levels of famers, commonly acquiring antibiotics without prescriptions and frequent storage of critically important antibiotics) will be largely generalizable to other areas in rural China where backyard pig farms remain common. Small-scale backyard pig farms are quite homogenous, and previous studies have often used data from a limited number of collection sites (Qiao et al., 2016; Wu, 2019; Zhang et al., 2017), and Shandong province has previously been used as a representative of eastern coastal and northern provinces (Qiao et al., 2016). We obtained a similar sample population in terms of farmers' sex and age distribution as other studies on backyard pig farms conducted in Sichuan, China (Wanli et al., 2007) and Beijing, China (Zhilu and Haifeng, 2011). Although many farmers in our study had other animals on their farms (e.g. ducks, chickens, mink, goats), our questions focussed on antibiotic use for pigs, so our results should not be assumed to be wholly representative of the farmers' knowledge, attitudes and practices towards antibiotic use in general in animals. It is also less clear to what extent the specific results (particularly in terms of types of antibiotics stored) can be generalized to other countries in the region, since farmers' behaviours will be influenced by local regulations of antibiotic use and livestock management, market availability of antibiotics, access to antibiotics, and economic factors. Backyard farm productivity rates, however, are considered to display little variation between low resource countries (Van Boeckel et al., 2015), and our study methodology and survey provide a template for how similar investigations could be conducted in other resource-poor settings, helping to address a critical unmet need: understanding the social and behavioural drivers of antibiotic use and resistance in agriculture.

5. Conclusion

Several policies regarding antibiotic use and antibiotic resistance have recently been implemented in China in human and animal medicine (National Health and Family Plan Commission, 2016; Walsh and Wu, 2016; Wu, 2019). So far, these policies have mostly focused on urban areas, and on large commercial farms. Our study contributes important information for improving antibiotic use in backyard pig farms in rural China, particularly concerning farmers' knowledge, attitudes and practices towards antibiotic use, and should prove useful in helping target education efforts to farmers. Most participants in our study did not report being worried about antibiotic resistance, consistent with previous studies among pig farmers conducted in Spain (Moreno, 2014) and Switzerland (Visschers et al., 2014). Other studies have found similarly low levels of worry about antibiotic resistance, compared with concerns about financial and legal issues in pig farming (Eltayb et al., 2012; Friedman et al., 2007; Visschers et al., 2015).

Consistent with previous studies (Lathers, 2001; Xiaocheng et al., 2013), participants showed high levels of trust in veterinarians. This trust suggests that veterinarians could play an important outreach role in educating farmers on using antibiotics more responsibly, as well as on advising about ways to reduce the need for antibiotics, such as internal and external biosecurity, improved management and improved feeding routines (Eltayb et al., 2012; Visschers et al., 2014). Furthermore, pig farmers should be encouraged to consult with veterinarians or paraprofessionals when their pigs are ill to ensure a proper clinical diagnosis, particularly if they are considering initiating treatments. The Chinese government has recognised that efforts are therefore needed to ensure that veterinarians, para-veterinarians and animal pharmacists are adequately trained, including to advise on responsible antibiotic use (Xiao and Li, 2017; Wu, 2019). These efforts must take into account the potential financial conflicts of interest that can exist when health providers rely on profits from sales of medicines, and which have previously contributed to antibiotic overuse in human medicine in China (He et al., 2019). Ultimately, regulations to restrict availability of antibiotics directly to farmers without prescriptions also need to be implemented (Graham et al., 2017), and this must be accompanied by sufficient accessibility to veterinarians for farmers.

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Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.prevetmed.2019.104858.

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